Influence of harvest time on yield and seed quality of desi type chickpeas

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Abstract

Demand by export markets for premium-quality chickpeas (*Cicer arietinum*) and the requirement by growers to maximise crop returns are factors directing production. Timing of harvest can play an important role in helping the industry meet these demands. Delays in harvesting after the crop has fully matured result in yield losses through pod drop and shattering. Seed quality deteriorates, especially from re-wetting 'on-stalk', affecting seed storability and end-product quality.

The influence of harvest time on yield and seed quality of the desi type chickpea variety 'Amethyst' was assessed over the 1997/98 and 1998/99 harvest seasons. Seed was harvested early, on-time and late from field sites at Wagga Wagga and Tamworth, New South Wales. The benefits of harvesting early depend largely on the prevailing weather conditions. During fine, warm weather, when there is rapid, uniform drying of the crop, harvesting should commence when late-maturing seed in the apical pods dry to 15% moisture content. Yield loss due to unthreshed pods is likely to occur in early harvests when cool, wet weather prevails during ripening, resulting in immature seeds in the apical pods.

In this study, seed quality was enhanced with earlier harvesting. Germination energy was high, seed size large and uniform, seed coat colour intense, and mould levels and postharvest breakage low. Delays in harvesting resulted in a substantial loss in seed quality, with weather damage becoming more pronounced following unseasonal rains. Yield losses increased to over 20% in late harvested crops as a result of preharvest pod drop and shattering, and shattering due to impact at harvest. A high level of unthreshed pods in the harvested seed resulted from re-wetting by rain.

Seed harvested over 13% moisture content would require cooling and/or drying to maintain quality attributes and meet market demands. The costs of this conditioning process would need to be weighed against the benefits of reduced harvest losses and better quality seed.

Introduction

Harvesting pulses early can substantially reduce yield losses and enhance seed quality. In Australia, pulses are typically late harvested, following on from harvesting of cereal crops. A change in harvest management of pulses, from late to early harvesting, is gaining momentum within the industry. Delays in harvesting pulse crops such as field peas (*Pisum sativum*) result in yield losses due to preharvest pod drop and shattering, and shattering due to impact at harvest (Cassells and Green 1998). Periods of wet and dry weather cause alternate contraction and expansion of the pod and weakening of the pod hinge (Knott 1985). During wet harvests, yield losses in excess of 20% can occur, especially for field peas, where a rambling growth habit and weak stems predispose mature pea crops to lodge which impairs machine harvesting (Heath and Hebblethwaite 1985). Chickpea crops typically have a more erect growth habit. Ripe chickpea crops, however, also lodge and severely lodged, late harvested crops are likely to increase shattering due to impact at harvest.

Chickpeas destined for the human consumption market need to be visually appealing. Seed size, colour, and split or broken seed are important parameters that affect visual quality (Siddique et al. 1998). Chickpea seed quality deteriorates with weathering of the standing crop, reducing seed viability and increasing the percentage of split and damaged seed when mechanically harvested (Knights 1993). The colour of the seed coat darkens and seeds are more prone to break during handling (Cassells 1998). The increased propensity of seeds to break poses a problem for storers and handlers since unacceptable levels of defective seed may result on outturn.

This study quantifies yield and yield losses, and identifies changes in seed quality resulting from different times of harvest. The information provides a basis from which growers can make an informed decision on harvesting strategies for their desi chickpea crops.

Materials and methods

The study was conducted over the 1997/98 and 1998/99 harvest seasons at the Agricultural Research Institute, Wagga Wagga, and the Tamworth Centre for Crop Improvement, Tamworth, both in New South Wales. Desi type chickpea seed of the 'Amethyst' variety was obtained from Tamworth and used at both sites.

Plot design and plant density

The experimental plots were sown in a randomised plot design. Eight replicate plots were sown for each harvest time. The plots at Wagga Wagga measured 1.6 m × 12 m and those at Tamworth 1.8 m × 10 m. The plant densities obtained were 37 and 42 plants m^{-2}, respectively, for the 1997/98 and 1998/99 Wagga Wagga harvests, and 32 plants m^{-2} for the 1998/99 Tamworth harvest.

Harvesting

The crop was harvested 'early' (the earliest time the header could thresh the seed), 'on-time' (approximately a week after the early harvest) and 'late' (2 weeks after the 'on-time' harvest). A larger number of plots sown at Wagga Wagga for the 1998/99 harvest enabled a 'later' harvest 2 weeks after the 'late' harvest. Yield loss due to pod drop and shattering was determined before and after harvest by counting seeds on the ground using a 1 m^2 quadrant at 3 points within each sub-plot. The amount of unthreshed pods in the harvested sample was also assessed.

Quality assessment

All quality tests, except for mycology, were undertaken on each of eight replicate samples collected from sub-plots at different harvest times. Results are reported as an average of values obtained for seed harvested from the eight sub-plots. Mould infection levels were determined on four of the eight replicate samples taken at each harvest time. The quality tests were:

Moisture content. The moisture content of the harvested seed was determined using a standard oven-dried method (ISO 1985).

Germination. Germination energy was assessed using the ISTA guidelines (ISTA 1993). Seeds were germinated for 8 days between moistened sheets of paper at 20°C under artificial light.

Colour. The colour of whole, split seed and flour was measured using a Minolta Croma Meter with a CR-310 (50 mm diameter) measuring head. Readings were taken using the Commission Internationale de I'Eclairage L*a*b* system (Hunter and Harold 1987), where: L* quantifies brightness, dark to light (0 to 100); a* redness (–ve green to +ve red); and b* yellowness (–ve blue to +ve yellow).

Breakage. The propensity of the seed to break was determined at harvest moisture contents and after conditioning seed at 18°C and 55% relative humidity for 3 weeks. Breakage was measured by processing 100 g of whole seed for 4 minutes using a Steinlite™ Model CK2-M maize breakage tester. The processed samples were sieved to remove all broken seed and percentage breakability calculated from the weight of broken seed compared to total seed weight.

Seed size and weight. Size of harvested seed was measured by sieving a 1 kg sample through 8, 7, 6 and 4.8 mm round aperture size screens fitted to a mechanical shaker that was set on a cycle of 30 shakes. The proportion of seed remaining above each screen size was reported as a percentage of the total weight. Seed weight was determined per 100 seeds.

Mycology. Food Science Australia, Sydney, assessed fungal counts. The samples were assessed by direct plating onto dichloran 18% glycerol agar (DG18) for xerophilic fungi, and dichloran rose bengal chloramphenicol agar (DRBC) for total yeast and mould counts.

Results

Harvest conditions

The 1997/98 and 1998/99 harvests provided extremely variable conditions for crop development and seed maturation. The 1997/98 harvest at Wagga Wagga was hot and dry, with the ripe seed drying rapidly in the standing crop from 20% to 11% moisture content. In contrast, the 1998/99 harvest was wet and cool at both harvest sites, which resulted in continual growth of the plants and poor uniformity of crop development. Humid conditions favoured the development of field moulds. Plants, pods and seed at both study sites were heavily infected with the fungus *Ascochyta* blight (*Ascochyta rabiei*) and to a lesser degree grey mould (*Botrytis cinerea*).

Harvest yield

Delays in harvesting resulted in losses in yield due to pod drop and shattering (Table 1). Harvest losses were accentuated in the wet 1998/99 season with pod drop and shattering accounting for up to 15% of total losses. Unthreshed pod loss was high in early harvested samples where seed in immature apical pods was not threshed. Rewetting of pods following rainfall also reduced the efficiency of the plot harvester to thresh seed.

Seed quality assessment

Post-harvest breakage. The propensity of the seed to break increased with later harvest and was higher in the drier pre-conditioned samples (Table 2). Postharvest breakage of samples collected from the late 1998/99 harvest at Wagga Wagga was 17.9% for seed at 8.3% moisture content. Following conditioning to a moisture content of between 11 to 12% (wet basis), breakage in these samples was reduced to an average 5.1%.

Seed size. Seed size and weight decreased with later harvest. Rainfall over the harvest season resulted in swelling of the ripe seed, increasing seed size and weight.

Germination energy. Germination energy decreased with later harvest. Rainfall during the 1998/99 harvest had a detrimental effect on seed viability, with germination energy of late harvested seed collected from Tamworth reduced to 63.8%.

Mycology. In the 1998/99 season, both cropping sites were heavily contaminated with the fungus *A. rabiei* and to a lesser degree *B. cinerea*. *Alternaria* and *Cladosporium* species were present on seeds collected from both harvest seasons. *Aspergillus flavus* and *A. niger* were detected in seed harvested during the wet, humid 1998/99 season, and delays in harvesting during this period increased the level of mould infection on seeds.

Table 1. Potential seed yield and harvest loss for desi type chickpeas, variety 'Amethyst'.

Harvest time	Harvest date	Average moisture content (%, w.b.)	Header yield (t ha^{-1}, dry wt)	Yield from unthreshed pods in harvest sample (t ha^{-1}, dry wt)	Shatter on ground		Total potential yield (t ha^{-1}, dry wt)	Harvest loss (%)	Harvest loss due to shatter only (%)	Rainfall between harvest times
					Preharvest (t ha^{-1}, dry wt)	Postharvest (t ha^{-1}, dry wt)				
Agricultural Research Institute, Wagga Wagga (NSW)										
1997/98 harvest season										
Early	22/11/97	12.1	1.70	0.14	–	0.044[a]	1.88	10	2	0[b]
On-time	25/11/97	9.0	1.81	0.04	–	0.057[a]	1.91	5	3	0
Late	16/12/97	10.8	1.38	0.21	–	0.204[a]	1.80	23	11	17
1998/99 harvest season										
Early	4/12/98	13.3	2.04	0.13	0.000	0.110	2.28	10	5	2[b]
On-time	8/12/98	11.8	1.94	0.12	0.005	0.163	2.22	13	8	0
Late	23/12/98	11.8	1.66	0.32	0.084	0.208	2.18	24	13	44
Later	5/01/99	8.3	1.48	0.22	–	0.230[a]	1.93	23	12	4
Tamworth Centre for Crop Improvement, Tamworth (NSW)										
1998/99 harvest season										
Early	23/12/98	13.5	2.91	0.11	0.011	0.518	3.55	18	15	4[b]
On-time	30/12/98	9.5	3.19	0.02	0.036	0.296	3.54	10	9	0
Late	13/01/99	9.4	2.90	0.06	0.038	0.484	3.48	17	15	31

[a] combined pre and postharvest shatter
[b] rainfall over week before harvest time

Table 2. Seed quality assessment of desi type chickpea, variety 'Amethyst'.

Harvest time	Harvest date	Seed moisture content (%, w.b.)	Seed breakage (%)		Seed size (%) Screen aperture (mm)				100 seed weight (g)	Germination energy (%)	Mould infection[a] (%)	
			Pre-conditioned	Post-conditioned	8.0	7.0	6.0	4.8			DG18	DRBC
Agricultural Research Institute, Wagga Wagga (NSW)												
1997/98 harvest season												
Early	22/11/97	12.1	1.0	0.9	0.1	12.3	76.6	–	16.5	96.4	16	14
On-time	25/11/97	9.0	0.9	1.0	0.0	7.9	77.7	–	15.8	97.8	3	21
Late	16/12/97	10.8	6.9	4.6	0.0	12.9	75.2	–	16.1	94.6	7	18
1998/99 harvest season												
Early	4/12/98	13.3	0.4	0.4	0.7	42.8	53.9	2.5	18.4	95.6	33	48
On-time	8/12/98	11.8	0.3	0.6	0.4	42.4	55.0	2.2	18.5	95.8	49	66
Late	23/12/98	11.8	4.5	6.7	0.2	56.0	42.0	1.9	18.8	87.8	98	100
Later	5/01/99	8.3	17.9	5.1	0.2	44.0	52.3	3.5	17.7	83.8	90	99
Tamworth Centre for Crop Improvement, Tamworth (NSW)												
1998/99 harvest season												
Early	23/12/98	13.5	0.4	1.4	0.3	32.2	60.3	6.5	17.1	93.3	88	99
On-time	30/12/98	9.5	4.0	3.7	0.4	19.3	69.1	10.4	16.3	82.9	100	100
Late	13/01/99	9.4	21.2	14.4	0.3	24.6	67.6	7.1	16.1	63.8	99	100

[a] Mould infected seeds% of total seeds – DG18 for xerophilic fungi and DRBC for total yeast and moulds (see text).

Seed coat colour. Seed coat colour darkened and the typical strong yellow hue of the 'Amethyst' variety turned to brown with later harvest (Table 3). The low a* value obtained for 1998/99 early harvested samples indicates the presence of immature, green seeds. The difference in b* value obtained for on-time (24.2) and late (21.1) harvested seed collected from Wagga Wagga during the 1998/99 season shows substantial loss of yellowness. The seed collected from Wagga Wagga during the 1997/98 harvest was lighter compared to seed collected from both sites during the following harvest. The colour of the cotyledons, referred to as dhal, was generally lighter and less yellow for late harvested seed. Similarly the colour of flour, referred to as besan, was lighter and substantially less yellow.

Discussion

Late harvest of desi type (variety 'Amethyst') chickpea crops resulted in excessive yield losses due to pod drop and shattering. The degree of loss increased when mature, desiccated pods were exposed to a cycle of wetting and drying over the harvest period. Yield losses due to pod drop and shattering of up to 15% can be expected in late harvested crops. It is well recognised that excessive delays in harvest increase yield losses due to pod dehiscence and shatter (Ellis et al. 1988; Knights 1993; Delouche 1998). The prostrate habit of late harvested, lodged crops also contributed to an increase in losses due to shatter when plants were mechanically harvested. Losses due to lodging were more of a problem during the late 1998/99 harvest at Tamworth where the high-yielding, dense crop accentuated shattering due to impact. Re-wetting of mature pods is likely to increase yield loss due to less efficient threshing of seed. Following rainfall, sufficient time should be allowed to enable pods and seed to dry down to moisture levels where seed is readily threshed.

Early harvesting of chickpea crops requires a uniform rate of crop maturation. Chickpeas typically lack synchrony of flowering within individual plants (Erskine et al. 1988), with seed set and maturation progressing from the basal to apical pods on the rachis. In this study, chickpea seed varied in maturity within and between plants, especially where wet weather was experienced during seed ripening. Immature seed in apical pods increased the percentage of green seeds in early harvested samples. A maximum of 1% by weight of seeds of poor colour (including green seeds) is allowable in export quality, machine-dressed desi chickpeas (Anon. 1999). Timing of an early harvest of a chickpea crop will depend largely on maturation of seeds in apical pods. During fine, warm weather, when there is rapid, uniform drying of the crop, it is recommended that harvesting should commence when late-maturing seeds in the apical pods dry to 15% moisture content to reduce the level of green seeds and unthreshed pods in the harvested sample.

Seed quality was enhanced through early harvesting. In early harvested seed, germination energy was high, seed size large and uniform, seed coat colour intense, and mould levels and postharvest breakage low. Late harvested, weathered seed was more prone to fracture during harvest and subsequent handling. Threshing of weathered chickpeas has also been shown by Knights (1993) to increase seed coat damage and percentage of spit seeds. Weathered seed harvested at low moisture contents was especially susceptible to breakage during handling, and could pose problems for storers and handlers in meeting standards for defective seeds at outturn. Delouche (1988) reported that the structure of large legume seeds makes them susceptible to physical injury from the mechanical forces associated with harvesting, threshing and handling, especially when seed moisture content is less than about 11 to 12% (wet basis).

Seed coat colour and uniform seed size are major drivers of export sales (Siddique et al. 1998). The majority of Australia's export customers prefer a light to medium brown seed coat colour. Darkening and loss of hue from the seed coat results in a less marketable product. Darkening of the seed coat is thought to be due to oxidation of polyphenol compounds, a chemical process that occurs in other pulses (Black and Brouwer 1998). In this study, the seed coat colour of 'Amethyst' varied between location and season. Humidity and temperature after seed ripening play a role in accelerating seed coat darkening and loss of hue. The hot, dry 1997/98 harvest at Wagga Wagga produced 'Amethyst' seed with light yellow to brown seed coat colour. The cool, humid conditions that prevailed at both study sites during the 1998/99 harvest resulted in early harvested seed that was darker and browner. Consumer preference is for dhal that is golden yellow in colour (Anon. 1998). Dhal and besan produced from early harvested 'Amethyst' seed was bright with a strong yellow hue. Dhal and besan produced from late harvested 'Amethyst' seed was lighter and yellowness was less intense.

Weathering of ripe seed increased mould levels and substantially reduced germination. Threshing of late harvested seed has also been shown to have a detrimental effect on germination (Knights 1993). Testae quality and physiological age of seeds have been shown by Ellis et al. (1988) to influence germination energy, and harvesting the ripe chickpea crop as early as practicable was recommended to minimise testae damage and ageing. Seed viability provides a good indication of initial seed condition and storability. Climatic conditions during the post-maturation, preharvest period can initiate deteriorative processes that reduce the storage potential of seeds (Delouche 1988). Cassells (1998) showed that weathered chickpeas exhibited poor storability characteristics when stored under moderate conditions of temperature and relative humidity.

Frequent rainfall during the period of seed development and ripening during the 1998/99 season resulted in heavy fungal infection of plants and pods with the fungus *A. rabiei*, and to a lesser degree *B. cinerea*. Fungal infection has been found to have a detrimental effect on seed viability (Christensen 1972).

Table 3. Colour of whole seed, dhal and besan of the desi type chickpea, variety 'Amethyst'.

Harvest time	Harvest date	Whole seed			Dhal Colour parameters[a]			Besan		
		L*	a*	b*	L*	a*	b*	L*	a*	b*
Agricultural Research Institute, Wagga Wagga (NSW)										
1997/98 harvest season										
Early	22/11/97	47.0	7.7	22.3	–	–	–	–	–	–
On-time	25/11/97	47.9	7.3	23.7	–	–	–	–	–	–
Late	16/12/97	46.9	8.7	22.1	–	–	–	–	–	–
1998/99 harvest season										
Early	4/12/98	44.9	9.4	22.2	66.1	8.4	39.8	89.5	–1.1	28.2
On-time	8/12/98	46.2	10.1	24.2	65.5	8.8	40.2	89.5	–0.9	28.3
Late	23/12/98	44.6	12.1	21.1	66.4	8.6	38.8	89.9	–0.9	25.3
Later	5/01/99	45.0	11.5	21.1	66.2	9.0	39.2	90.1	–0.9	24.8
Tamworth Centre for Crop Improvement, Tamworth (NSW)										
1998/99 harvest season										
Early	23/12/98	43.4	11.0	19.5	64.9	9.0	39.0	89.7	–1.0	25.2
On-time	30/12/98	44.8	10.6	19.8	65.4	9.3	38.9	89.8	–0.7	23.9
Late	13/01/99	42.2	10.5	16.6	65.7	8.5	35.1	90.3	–0.5	20.2

[a] Colour measured using the Commission de l'Eclairage L*a*b* system where L* (0 to 100) represents dark to light, a* (–60 to +60) green to red, and b* (–60 to +60) blue to yellow.

Germination levels of heavily infected seed were reduced by up to 30% in late harvested seed. High mould levels also caused discolouration of the seed coat. Humid conditions were also conducive to infection by numerous field type fungi, including *Alternaria, Aspergillus, Cladosporium*, and *Penicillium* species.

Conclusion

Harvesting desi type chickpeas as early as practicable can provide growers with substantially higher yields and premium quality seed. Storers benefit through seed with improved storage and handling characteristics. Marketeers benefit through a greater availability of premium-quality seed. The variable maturity of seed between basal and apical pods is a limiting factor in early harvesting, especially when cool, wet and humid conditions prevail. Harvesting should commence when the late maturing seeds in the apical pods dry to 15% moisture content. Early harvested seed may require cooling and/or drying to meet industry and marketing moisture content standards. The costs of this conditioning process would need to be weighed against the benefits of reduced harvest losses and better quality seed.

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